LOW COMPLEXITY METHOD FOR REDUCING PAPR IN FRFT-OFDM SYSTEMS

CROSS-REFERENCES AND RELATED APPLICATIONS

[0001] This application is a continuation-in-part of US patent application Ser. No. 14/886,056, filed Oct. 18, 2015, which claims priority of the international application PCT/CN2013/082060, filed Aug. 22, 2013, which claims priority of Chinese Application No. 201310142185.5, entitled "A low complexity PAPR suppression method in FRFT-OFDM system", filed April 22, 2013, which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] Field of the Invention

[0003] The invention relates to a low complexity method for suppression of PAPR (peak-to-average power ratio) in FRFT-OFDM (Fractional Fourier Transform-Orthogonal Frequency Division Multiplexing) systems, and belongs to the field of broadband wireless digital communications technology. This method can be used to enhance the efficiency of transmitting amplifiers and the transmission performance.

[0004] Description of the Related Art

[0005] Traditional Orthogonal Frequency Division Multiplexing (OFDM) system converts the serial high-rate data stream to parallel low-rate data streams by Discrete Fourier Transform (DFT), which makes the OFDM system have good performance in the multipath fading channel. However, in the double-selective channel, the orthogonality between subcarriers of OFDM system may be compromised due to inter-carrier interference. To overcome this issue, Martone Massimiliano proposed an OFDM system which is based on fractional Fourier transform (FRFT), as shown in FIG. **1**. The FRFT-OFDM system has better transmission performance than traditional OFDM system in the fast varying channel. Meanwhile, DFRFT (Discrete Fractional Fourier Transform) has similar computational complexity as FFT (Fourier transform) and is easy to implement. Therefore, FRFT-OFDM system has good engineering value.

[0006] However, high PAPR is a serious issue in FRFT-OFDM systems, which results in high operating cost and low efficiency of the system. At present, the FRFT-OFDM system uses the same methods as the traditional ones of OFDM system for PAPR suppression. The methods for PAPR suppression in traditional OFDM system include: limiting amplitude, selective mapping (SLM) and part of the transmission sequence (PTS). When applying the traditional SLM and PTS methods to the FRFT-OFDM system, the performance of the system has been improved significantly, but the two methods have the problem of large computational complexity as shown in FIG. **2** and FIG. **3**. As shown in FIG. **4**, some scholars have proposed using the OCSPS and CSPS methods to solve the problem of large computational complexity in the PTS method. However, due to the existence of periodic of chirp in the fractional Fourier Transform, the method can't be directly applied to the FRFT-OFDM system.

[0007] In the following paragraph, we introduce the fractional Fourier Transform, its discrete algorithm and the fractional convolution theorem.

[0008] Fractional Fourier Transform is a generalized form of Fourier Transform. As a new tool of time-frequency analysis, FRFT can be interpreted as a signal in the time-frequency plane of the axis of rotation around the origin. FRFT of signal x(t) is defined as:

$$X_p(u)=\{F_p[x(t)]\}(u)=\int_{-\infty}^{+\infty}x(t)\cdot K_p(t,u)dt \tag{1}$$

wherein p=2·α|π is the order of the FRFT; α is the rotation angle; $F_p[\cdot]$ is the operator notation of FRFT; and $K_p(t,u)$ is the transform kernel of FRFT:

$$K_p(t,u)= \tag{2}$$

$$\begin{cases} \sqrt{\dfrac{1-j\cdot\cos\alpha}{2\pi}}\cdot\exp\left(j\cdot\dfrac{t^2+u^2}{2}\cdot\cos\alpha-j\cdot u\cdot t\cdot\csc\alpha\right) & \alpha\neq n\pi \\ \delta(t-u) & \alpha=2n\pi \\ \delta(t+u) & \alpha=(2n\pm1)\pi \end{cases}$$

[0009] Inverse transform of FRFT is:

$$x(t)=\int_{-\infty}^{+\infty}X_p(u)\cdot K_{-p}(t,u)du \tag{3}$$

[0010] Discrete fractional Fourier Transform (DFRFT) is required in the practical application. At present, there are several different types of DFRFT, which have different accuracy and computational complexity. The method proposed by Soo-Chang Pei which samples input and output components is selected in this invention. The algorithm can maintain similar accuracy and computational complexity as the fast decomposition algorithms (the computational complexity is O(N $\log_2$ N), where N is the number of sample points), while keeping orthogonality of DFRFT conversion nuclear by defining the input and output sampling interval. It can recover the original signal at the output end by inverse discrete transformation.

[0011] The input and output of FRFT are sampled at $\tilde{x}^{(l)}(n)$ and Δu, when M≥N, and the sampling interval satisfies:

$$\Delta u\cdot\Delta t=|S|\cdot 2\pi\cdot\sin\alpha/M \tag{4}$$

wherein M is the output sampling points of fractional Fourier domain; N is input sampling points in the time domain; |S| is a positive integer which is a mutually prime number of M (usually taken as 1). DFRFT can be expressed as:

$$\begin{cases} X_\alpha(m)=A_\alpha\cdot e^{\frac{j}{2}\cdot cot\alpha\cdot m^2\cdot\Delta u^2}\sum_{n=0}^{N-1}e^{\frac{j}{2}\cdot cot\alpha\cdot n^2\cdot\Delta t^2}\cdot e^{-j\cdot\frac{2\pi\cdot n\cdot m}{M}\cdot x(n)}, & \alpha\neq D\cdot\pi \\ X_\alpha(m)=x(m) & \alpha=2D\pi, \\ X_\alpha(m)=x(-m) & \alpha=(2D+1)\pi \end{cases} \tag{5}$$